Bonneville Power Administration
Fish and Wildlife Program FY99 Proposal Form

Section 1. General administrative information

Numerical Evaluation of Flow Modification on Salmonid Migration

Bonneville project number, if an ongoing project 9112

Business name of agency, institution or organization requesting funding
The University of Michigan, Ann Arbor

Business acronym (if appropriate) UMich

Proposal contact person or principal investigator:

Name	Dr. Sanjiv K. Sinha
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Subcontractors.

Organization	Mailing Address	City, ST Zip	Contact Name

NPPC Program Measure Number(s) which this project addresses.
Sections 5.0E, 5.0F, 5.2, 5.4

NMFS Biological Opinion Number(s) which this project addresses.
BO ID #s 4, 10, 13g

Other planning document references.

Subbasin.

Short description.
Improve conditions for Salmonid migration in Columbia/Snake rivers by modifying the flow field using a system of flow modification devices known as vanes. Flow-field, with and with-out the vanes, will be simulated using a 3-dimensional numerical model.

Section 2. Key words

Mark	Programmatic Categories	Mark	Activities	Mark	Project Types
X	Anadromous fish		Construction	+	Watershed
	Resident fish		O & M		Biodiversity/genetics
	Wildlife		Production	+	Population dynamics
	Oceans/estuaries	X	Research		Ecosystems
	Climate		Monitoring/eval.	X	Flow/survival
	Other		Resource mgmt		Fish disease
			Planning/admin.		Supplementation
			Enforcement	+	Wildlife habitat enhancement/restoration
			Acquisitions		

Other keywords.
Computational fluid dynamics, Numerical modeling, Flow turbulence, Hydrodynamics, Vanes, Flow modification, Downstream migration

Section 3. Relationships to other Bonneville projects

Project #	Project title/description	Nature of relationship

Section 4. Objectives, tasks and schedules

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task

1	Select a 4-5 mile long reach in Columbia/Snake mainstem		
2	Generate a three-dimensional numerical grid/mesh for the selected reach		
3	Undertake a numerical simulation for flow field without the presence of any vanes		
4	Undertake a numerical simulation for flow field with vanes present		
5	Evaluate the numbers and orientations of vanes for optimum results		
6	Compare 3, 4 and 5 and draw conclusions		

Objective schedules and costs

Objective #	Start Date mm/yyyy	End Date mm/yyyy	Cost %
1	10/1998	10/1998	8.00%
2	11/1998	12/1998	16.00%
3	1/1999	3/1999	24.00%
4	4/1999	6/1999	24.00%
5	7/1999	7/1999	16.00%
6	8/1999	9/1999	12.00%
			TOTAL 100.00%

Schedule constraints.
None

Completion date.
1999

Section 5. Budget

FY99 budget by line item

Item	Note	FY99
Personnel	S. K. Sinha's Salary : 0.75 yr@ $72K/yr; A. I. Sirviente's Salary: 0.25 yr@ $78K/yr	$73,500
Fringe benefits	@ 30% of the salary	$22,050

Supplies, materials, non-expendable property	1000 hours on mainframe computer @ $10/hour	$10,000
Operations & maintenance	None	$0
Capital acquisitions or improvements (e.g. land, buildings, major equip.)	None	$0
PIT tags	# of tags: 0	$0
Travel	Attend meetings/present results etc	$3,000
Indirect costs	@58% of the above expenses	$62,959
Subcontracts	0	$0
Other	Faxes/phone etc	$491
TOTAL		$172,000

Outyear costs

Outyear costs	**FY2000**	**FY01**	**FY02**	**FY03**
Total budget	$0	$0	$0	$0
O&M as % of total	0.00%	0.00%	0.00%	0.00%

Section 6. Abstract

This proposal seeks to study the modification of river flow patterns and its impact on the migration of downstream migrating Salmonids. The flow and turbulence fields will be modified using submerged vanes. The flow patterns, for the with and without vane scenarios, will be simulated computationally using a recently developed fully three-dimensional numerical model capable of resolving natural stream flow physics in detail.

Over a period of nine months, it is expected that the optimum vane distribution as well as their orientation will be determined for a specific four-mile long reach of the Columbia River. It is hoped that this short pilot study would provide a set of definitive quantitative formulations correlating the effects of vanes (and other similar flow modification devices) on the surrounding flow field and the downstream migration patterns of juvenile Salmonid.

Section 7. Project description

a. Technical and/or scientific background.

a.1. Introduction:

The management of living aquatic resources is a complex process involving an amalgamation of biological, economic, social, and political factors. Such complexities have led to delayed response to a variety of aquatic resource management issues. For example, as part of the 1994 Fish and Wildlife Program, Northwest Power Planning Council (NPPC) attributes the construction and operation of dams and reservoirs as one of the primary reasons for massive changes in physical, chemical, and biological characteristics of fish habitat in Columbia/Snake river system. Construction and operation of dams are linked with changes in the ambient water temperatures, both upstream and downstream of dams, resulting in an increase in the migration time of the fish. Change in migration time is directly linked with increased predation and disease among downstream migrating salmonids. Another important effect of the dams is the altered seasonal pattern of river flow that results in less turbulent and steadier flow than would otherwise be possible in nature.

Reduced turbulence, slower velocities, and enhanced steadiness in the flow field in the upstream reservoir, results in smaller channel length which act like "rivers". Such flow characteristics have been hypothesized to be detrimental to the downstream migration of juvenile Salmon. It is the purpose of this research proposal to seek funding for an intensive pilot study to evaluate the effects of enhancing hydrodynamic flow features believed to be responsible for the downstream migration of the Salmonids. Specifically, the effects of putting a series of submerged flow modification devices (such as submerged vanes) to increase turbulence and un-steadiness in the flow field will be studied. The flow field will be analyzed using a recently developed state-of-the-art fully three-dimensional numerical model for flow through natural streams. Use of the numerical model would allow for an alternative way of studying the problem without resorting to more expensive, site-specific, and tedious physical model or field studies.

a.2. Submerged vanes:

Submerged vanes are vortex generating devices that have been used for a variety of purposes such as: to protect against stream bank erosion, reduce sediment entrainment from water intakes structures, and to correct shoaling problems in navigation channels [1,2,5,20]. In the last two decades, there has been an increase in the use of submerged vanes as sediment management devices as their small dimension and the relatively better alignment with the flow field (compared to dikes and groins etc.) lead to the required modifications of the flow field at less flow resistance and structural cost [4].

In the field, vanes are mounted on the riverbed with an angle to the prevailing flow direction. The pressure difference between the pressure and suction sides of the vane results in the creation of vortices that develop a transverse bed shear (see Figure 1 in Attachment). In alluvial rivers, this shear stress alters the bed slope, changing the cross-section of the river. The effectiveness of a vane system to generate the secondary circulation is dependent upon the vane height, depth, shape, and the angle of attack of the approach flow. Several experimental and theoretical studies have been undertaken in the recent past to analyze the effect of individual as well as system of vanes [5, 20]. Owing to obvious complexities of the flow, such studies were undertaken for simple shape geometry open channels (such as straight channel with rectangular cross-sections etc) only.

The most detailed and realistic study --due to the only recent advancements in computing resources and numerical algorithms-- describing the effects of vanes in a natural stream is attributed to *Sinha and Marelius* [6, 3]. The goal of their work was to explore the possibilities of developing a numerical tool robust enough to simulate flow through natural rivers with a series of vanes. The numerical model results were shown to have excellent agreements with detailed experimental measurements from a deformable bed channel laboratory study [3]. *Sinha and Marelius* [6] identified the flow features responsible for the transverse movement of sediment transport which included, among others, two counter-rotating vortices in the immediate vicinity of the vane (see Figure 2 in Attachment). On the pressure side of the vane, a horseshoe vortex was found to be located in a plane parallel to the vane, which induced particle movement downstream along the vane and upstream along the bed of the scour hole (see Figure 3 in Attachment). This process is similar to that observed upstream of bridge piers [4] but was never identified before in the flow field near vanes.

The flow features induced due to the presence of the vanes, namely downstream migrating secondary circulation currents (shown in Figure 1 and 2) and the horse-shoe vortex upstream of the vane (shown in Figure 3), have been considered as possible aids to downstream migrating salmonids. The additional effect of these features is to enhance turbulence anisotropy in the cross-section of the flow field. It is believed that these characteristics would aid the downstream migrating Salmonids.

a.3. Most significant work history (by key personnel):

The Principal Investigator (S. K. Sinha) has been directly involved on similar projects in the past. As outlined in the reference list, Prof. Sinha's experience has ranged from developing a fully three-dimensional model for natural river reaches [7-14] to applications of the numerical model past submerged vanes [3,6]. Since the proposed project involved application of a previously developed and extensively validated numerical model, the development time and any un-certainties associated with a new project are not present.

The Co-Principal Investigator (A. I. Sirviente) is a mechanical engineer who brings in a unique perspective to the stream flow problems. Prof. Sirviente's expertise includes viscous fluid flows and turbulence modeling [15-19]; and, would provide direction to the turbulence-related issues in the present project.

b. Proposal objectives.

b.1. Specific measurable objectives:

The objectives of this project are the following:

- Quantify the percent increase in turbulence levels in water due to the presence of the vanes in a given reach.
- Quantify the percent increase in secondary circulation strength at several cross-sections in the reach.
- Provide detailed data-bases for fully three-dimensional velocity and turbulence field information for the river reach for future studies.
- Quantify the optimum number and orientation of vanes needed in the river reach to generate the strongest secondary circulation and turbulence.
- Provide a quantitative analysis of using vanes and other flow modification devices for enhancement of fish habitat in Columbia/Snake River system.

b.2. Critical hypotheses/Underlying assumptions:

Unsteady turbulent flows are characteristics of natural streams in which the migrating juvenile salmonids utilize the hydraulic flow features (such as, stage waves, turbulent bursts and vortices) as aids in maximizing the downstream migration length. Thus, the reservoir management for maximum unsteady and turbulent flow hydraulics may be considered more appropriate for downstream migrating fish. Despite this, no empirical or mathematical quantifiable relationship currently exists which relates the movement of the salmonid to that of a change in flow volume/turbulence.

Computer simulation of complex flows, such as those encountered in natural streams, is limited by the level of grid refinement. The grid refinement restricts the size (or, alternatively, the resolution) of the problem. Depending upon the complexity of the river reach in concern, either a set of inter-connected models would be developed [previously done for Wanapum Dam tailrace reach, see 9 or 14] or the resolution of the problem in concern would be reduced.

c. Rationale and significance to Regional Programs.

c.1. Rationale and significance to regional programs:

Our belief that vanes are useful as flow modification devices, is based upon field and experimental studies undertaken by independent groups of researchers over several decades. We believe that vanes would find multi-purpose use (including, for example, in river restoration and habitat enhancement projects) in the Columbia/Snake river system. Similarly, use of numerical modeling as proposed in this study, is likely to prove to be a powerful tool to analyze flow physics and is expected to have a significant impact in traditional way to study stream flow problems.

We hope that through this pilot study, we will be able to generate enough interest among various project managers to seek a synergistic relationship in the future.

d. Project history

d.1 Project history

This is an entirely new topic and, although highly relevant and consistently recommended by the Independent Scientific Review Panel (ISRP), has never been funded before. Therefore, there is no project history to the best of the knowledge of the proponents of this work.

e. Methods.

e.1. Numerical Modeling:

The movement of fish in natural streams is believed to be dependent upon a variety of factors such as river flow rate, water depth, velocity and turbulent characteristics of the surrounding flow field, etc.. Until recently the complexity of a river flow field have remained unknown. Traditional methods to study river flows --such as field measurements and laboratory physical model studies-- are too expensive to undertake in details fine enough to provide insights into the physics of a highly three-dimensional flow. The geometrical complexities along with the changing upstream and downstream flow conditions induce very complex, three-dimensional turbulent shear flows which are characterized by secondary currents, vortex formation, flow reversal, turbulence anisotropy effects, etc.. These are some of the reasons that result in difficulty in detailed data collection in the field.

To facilitate the modeling of such flow structures in detail, the proposed work involves the application of a previously developed state-of-the-art numerical model [8,9]. Note that the proponents of this proposal were recently involved in several similar projects downstream of Wanapum and Priest Rapids Dams in the Mid-Columbia river (Grant County Public Utility District) [11-14]. In one of these projects (downstream of Wanapum Dam), flow through a three-mile stretch of the Columbia River is numerically simulated to answer a variety of fish migration related issues [9, 14, 18]. The numerical model developed as a part of that study was calibrated and validated in detail against both field as well as experimental data. The fully three-dimensional flow features under the natural conditions were shown to be satisfactorily predicted. Since the model formulation was done in generalized curvilinear coordinates, it allows great flexibility to apply the model to a variety of other river reaches. For example, the model was recently applied to two cooling ponds in central Illinois to address thermal stratification and its effect on indigenous fish in the lakes [7].

e.2. Benefits of numerical modeling over traditional techniques (such as direct field and experimental studies):

Flow through natural streams can be studied using analytical, experimental, or numerical models. Although easy to use and useful, efforts to analytically model open-channel streams have mostly been confined to highly idealized or simplified bathymetry problems. Analysis of complex real world flows is beyond the capability of any such model. The most accurate method that can be used to study natural river flows is through direct field measurements. Owing to site- and event-specific behavior of natural river flows, such studies are very expensive, time-consuming, and difficult to repeat. Similar problems, although to a lesser extent, are associated with physical models.

A calibrated and well-formulated numerical model can greatly ease the study of affecting flow parameters and offers an attractive (and economic) alternative for solving complex fluid mechanics problems encountered in practical engineering situations. However, up until today, although impressive, the progress in numerical modeling of flow through open channels had been such that the proposed schemes were not robust enough to be applied to a natural stream. Only recently *Sinha and colleagues* [6-8] proposed a method which is robust enough to be applied to natural river reaches of highly varying topography, and economical enough to be able to run on a work-station with minimal cost. This numerical model, therefore, provides an excellent starting point for studies similar to the presently proposed work.

e.3. Risks:

The strength of the proposed method lies in its being completely mathematical and, therefore, it does not alter the environment in any fashion to affect humans or wild life. Decisions based upon such an analysis, however, have the potential to provide enhanced habitat for the fisheries at minimal cost and expenditure.

f. Facilities and equipment.

f.1. Facilities and equipment:

The equipment needed to undertake this work are desktop workstations (for data analysis) and CPU time on main-frame supercomputers (such as Cray C-90 etc). The University of Michigan maintains a vast array of desktop workstations and would provide the equipment needed to undertake this study.

Upon a successful review of this proposal, a request for free CPU time at the National Science Foundation's (NSF) San Diego Supercomputing Center (SDSC) would be made. Although it is hoped that the CPU request from SDSC would be granted, a provision for $10K (towards 1000 hours, needed to complete the work) has been built in the budget of this work.

No other equipment is needed for this work.

g. References.

g.1. References:

1. Fukuoka S., and A. Watanabe. 1989. New bank protection method against erosion in the river. Proceedings of the Japan-China (Taipei) Joint seminar on natural hazard mitigation. Kyoto, Japan, July.

2. Jansen, P. Ph., L. van Bendegom, J. van den Berg, M. de Vries, and A. Zanen. 1979. *Principles of River Engineering*, Pitman Publishing Ltd., London, U.K.

3. Marelius, F., and S. K. Sinha. 1998. Experimental evaluation of flow past submerged vanes at high angle of attack. Manuscript to appear in the **Journal of Hydraulic Engineering**, American Society of Civil Engineers, May.

4. Melville, B., and A. J. Raudkivi. 1984. *Local scour at bridge abutments*, Nat. Roads Board New Zealand, RRU Seminar on bridge design and research, Auckland.

5. Odgaard, A. J., and A. Spoljaric. 1986. Sediment control by submerged vanes. **Journal of Hydraulic Engineering**, ASCE, 112(12), 1164-1181.

6. Sinha, S. K., and F. Marelius. 1998. Numerical evaluation of flow past submerged vanes. Manuscript submitted for possible publication to the **Water Resources Research**, American Geophysical Union, January.

7. Sinha, S. K., F. M. Holly Jr., and M. Dyer. 1998a. Three-dimensional numerical model and verification of thermal stratification in large cooling ponds. *Invited Paper*, **ASCE Annual Meeting**, Memphis, Tennessee (To Appear).

8. Sinha, S. K., L. J. Weber, and A. J. Odgaard. 1998b. Numerical evaluation of fish bypass outfall alternatives. Manuscript submitted for possible publication to **Hydro-review**, American Water Resources Association, January.

9. Sinha, S. K., F. Sotiropoulos, and A. J. Odgaard. 1998c. Three-dimensional numerical model for flows through natural rivers. **Journal of Hydraulic Engineering**, American Society of Civil Engineers, Vol. 124(1), 1-12, January.

10. Sinha, S. K.. 1997. An algebraic grid generation scheme for three-dimensional natural river reaches. **Communications in Numerical Methods in Engineering**, John Wiley & Sons, New York, John Wiley & Sons, New York, Vol. 13, 475-485, May.

11. Sinha, S. K., L. J. Weber, and A. J. Odgaard. 1997a. Numerical model studies for fish diversion at Wanapum/Priest Rapids development Part II: Three-dimensional numerical model for Flows through Priest Rapids dam tailrace reach. **IIHR Report No. 253**, University of Iowa, 74 pp., January.

12 Sinha, S. K., F. Sotiropoulos, and A. J. Odgaard. 1996a. Three-dimensional numerical model for turbulent flows through river reaches of complex bathymetry. Proceedings of

the **Sixth International Symposium on Flow Modeling and Turbulence Measurements**, Balkema Publishers, Rotterdam/Brookfield, 573-580, Tallahassee, Florida.

13. Sinha, S. K., L. J. Weber, and A. J. Odgaard. 1996b. Hydraulic model studies for fish diversion at Wanapum/Priest Rapids development Part IX: Identification of a fish bypass outfall location for Wanapum dam tailrace reach. **IIHR Report No. 252**, University of Iowa, 90 pp., November.

14. Sinha, S. K., F. Sotiropoulos, and A. J. Odgaard. 1996c. Numerical model studies for fish diversion at Wanapum/Priest Rapids development Part I: Three-dimensional numerical model for Flows through Wanapum dam tailrace reach. **IIHR Report No. 250**, University of Iowa, 194 pp., September.

15. Sirviente, A.I. and V. C. Patel. 1998. Turbulent Near Wake of an Axisymmetric Body. Accepted for publication in **AIAA Journal**.

16. Sirviente, A.I. and V. C. Patel. 1998. Experiments in Momentumless Turbulent Wake of a Jet-Propelled Axisymmetric Body. Accepted for publication in **AIAA Journal**.

17. Sirviente, A.I. and V. C. Patel. 1998. Experiments in Momentumless Turbulent Wake of a Swirling Jet-Propelled Axisymmetric Body. Submitted to **AIAA Journal**.

18. Sirviente, A.I. and A. J. Odgaard. 1997. A Study of the Effect of Surface Attraction Facilities on Flow over Fish Diversion Screens at Wanapum Dam. **IIHR Technical Report**, The University of Iowa, Iowa City, IA.

19. Parthasarathy, R., A. I. Sirviente, and V. C. Patel. 1993. LDV Measurements in Separated Flow on an Elliptic Wing Mounted at an Angle of Attack on a Wall. Transactions of the ASME, **Journal of Fluids Engineering**, Vol. 116, pp. 258-264.

20. Wang, Y., and, A. J. Odgaard. 1993. Flow control with vorticity. **Journal of Hydraulic Research,** IAHR, 31(4), 549-562.

Section 8. Relationships to other projects

Please see Section 3.

Section 9. Key personnel

9.1 **Sanjiv Kumar Sinha, Ph.D.**

CURRENT EMPLOYMENT:

• 107 EWRE Building, Department of Civil and Environmental Engineering, The University of Michigan, Ann Arbor, MI 48109-2125.

• Phone: (734) 647-1747; Fax: (734) 763-2275; e-mail: sanjiv@engin.umich.edu

EDUCATION:

• Ph.D. in Civil and Environmental Engineering Graduation: May 1996	The University of Iowa Iowa City, IA 52242
• M.S. in Civil Engineering Graduation: January 1992	University of Minnesota Minneapolis, MN 55414
• B.E. in Civil Engineering (Ist Class with Honors) Graduation: October 1989	University of Roorkee Roorkee 247667, India

CURRENT RESPONSIBILITIES:

• Fish behavioral modeling using Computational Fluid Dynamics. Develop advanced numerical techniques and enable a comprehensive quantitative analysis of velocity and turbulence parameters in natural streams. Use this data set to establish statistical correlations between the local flow field information and available fish path trajectories.

• Fully three-dimensional numerical modeling of unsteady contaminant transport in open channel flows. Special emphases on near-field dispersion to provide further insight into mitigating contamination problems in streams.

• Large Eddy Simulation of flow past bridge piers. Emphasis on understanding the variability introduced in the flow field by changing pier shapes and dimensions.

• Course instructor for "Fluid Mechanics" (Winter 1998 term Senior level undergraduate class).

• Thesis supervisor for Mr. Cheng-Ann Tan, Masters degree candidate. Thesis topic: Three-dimensional modeling of contaminant and thermal dispersion in surface water systems. (Note: Student's work awarded the "American Society of Mechanical Engineer 1997 Young Engineer Award" certificate).

RECENT PUBLICATIONS

• Sinha, S. K., L. J. Weber, and A. J. Odgaard. 1998. Numerical evaluation of fish bypass outfall alternatives. Manuscript submitted for publication to **Hydro-review**, American Water Resources Association, January.

• Sinha, S. K., and F. Marelius. 1997. Numerical evaluation of flow past submerged vanes. Manuscript submitted for publication to the **Water Resources Research**, American Geophysical Union, November.

• Marelius, F., and S. K. Sinha. 1998. Experimental evaluation of flow past submerged vanes at high angle of attack. Manuscript to appear in the **Journal of Hydraulic Engineering**, American Society of Civil Engineers.

• Sinha, S. K., F. Sotiropoulos, and A. J. Odgaard. 1998. Three-dimensional numerical model for flows through natural rivers. **Journal of Hydraulic Engineering**, American Society of Civil Engineers, Vol. 124(1), 1-12, January.

• Sinha, S. K.. 1997. An algebraic grid generation scheme for three-dimensional natural river reaches. **Communications in Numerical Methods in Engineering**, John Wiley & Sons, New York, John Wiley & Sons, New York, Vol. 13, 475-485, May.

9.2 Ana Isabel Sirviente, Ph.D.

CURRENT EMPLOYMENT:

• 204 NAME Building, Department of Naval Architecture and Marine Engineering, The University of Michigan, Ann Arbor, MI 48109-2125.

• Phone: (734) 647-9411; Fax: (734) 936-8820; e-mail: asirv@engin.umich.edu

EDUCATION:

• Ph.D. in Mechanical Engineering Graduation: July 1996	Iowa Institute of Hydraulic Research The University of Iowa Iowa City, IA 52242
• M.S. in Mechanical Engineering Graduation: December 1991	Iowa Institute of Hydraulic Research The University of Iowa Iowa City, IA 52242
• B.S. in Naval Architecture Graduation: June 1990	Polytechnic University of Madrid E.T.S. of Naval Engineering Madrid, Spain

CURRENT RESPONSIBILITIES:

• Numerical and experimental study of the effects of polymer addition in the structure of turbulence.

• Enhancement of turbulence closures applied to resolve free-surface flows.

• Development of a Viscous-Inviscid numerical scheme to simulate the turbulent free-surface flow around ship hulls.

• Further development of a numerical RANS-solver in conjunction with a Reynolds-Stress near wall turbulence closure. Applications of the later algorithm to solve junction flows with massive separation and momentumless wakes.

• Course instructor for "Marine Hydrodynamics I" (Senior level undergraduate class).

• Paper referee for AIAA Journal and for European Journal of Mechanics

RECENT PUBLICATIONS

• Sirviente, A.I. and V. C. Patel. 1998. Turbulent Near Wake of an Axisymmetric Body. Accepted for publication in **AIAA Journal**.

• Sirviente, A.I. and V. C. Patel. 1998. Experiments in Momentumless Turbulent Wake of a Jet-Propelled Axisymmetric Body. Accepted for publication in **AIAA Journal**.

• Sirviente, A.I. and V. C. Patel. 1998. Experiments in Momentumless Turbulent Wake of a Swirling Jet-Propelled Axisymmetric Body. Submitted to **AIAA Journal**.

• Sirviente, A.I. and A. J. Odgaard. 1997. A Study of the Effect of Surface Attraction Facilities on Flow over Fish Diversion Screens at Wanapum Dam. **IIHR Technical Report**, The University of Iowa, Iowa City, IA.

• Parthasarathy, R., A. I. Sirviente and V. C. Patel. 1993. LDV Measurements in Separated Flow on an Elliptic Wing Mounted at an Angle of Attack on a Wall. Transactions of the ASME, **Journal of Fluids Engineering**, Vol. 116, 258-264.

Section 10. Information/technology transfer

10. Products out of this work:

Any findings from this study would be reported in leading refereed Fisheries as well as Civil Engineering Journals. Findings from this work would also be presented at International/National conferences/forums of related discussions.